IMAGE PROCESSING APPARATUS AND METHOD

The present application claims priority to Japanese Patent Application No. 11-229181 filed August 13, 1999, the entire content of which is hereby incorporated by reference.

BACKGROUND OF THE INVENTION

FIELD OF THE INVENTION

The present invention relates to a digital image edge enhancement process.

DESCRIPTION OF THE RELATED ART

Digital images input from a digital camera and the like are subjected to various types of image correction. Various methods are used in the edge enhancement process, which is one of these image correction processes. For example, the edge is determined to be between pixels in the image process disclosed in Japanese Laid-Open Patent No. 5-108823. Furthermore, a threshold value which determines the edge is automatically calculated in the image process disclosed in Japanese Laid-Open Patent 10-143673.

Generally, when enhancing the sharpness of a digital image by an edge enhancement process, it is

desirable to adjust the thickness of the edge, i.e., the

range of edge enhancement, in accordance with the

characteristics of the photographic object. For example,

when photographing a building or man-made object, the

5   image appears to have an added border when the line of

the contour of the building is thickened, such that the

image appears unnatural. Accordingly, it is desirable to

enhance the line by narrowing the edge enhancement range

so as to not thicken the line in the case of buildings

10   and the like. Conversely, when enhancing an edge by

thinning the edge in the case of a human image and the

like, the enhancement often produces the opposite effect

of making the eyes and the like appear unnatural. For

this reason it is desirable to smoothly enhance the edge

15   by broadening the width of the edge in the case of human

images. That is, when photographing people, the

enhancement range must be somewhat broadened with

moderate edge enhancement. Numerous methods of automatic

edge enhancement have been proposed heretofore, but the

20   enhancement range must be input manually.

SUMMARY OF THE INVENTION

An object of the present invention is to

provide an image processing apparatus capable of

25   automatically accomplishing suitable edge enhancement.

2

Another object of the present invention is to provide an image processing apparatus capable of excellent edge enhancement for human images as well as image of man-made objects.

These and other objects are attained by an image processing apparatus, comprising edge detecting means for determining the presence/absence of an edge at each pixel of input image data; selecting means for selecting a weighting matrix corresponding to the position of the edge of each target pixel determined to have an edge by the edge detecting means; calculating means for calculating data of the target pixel and the pixels surrounding the target pixel using the weighting matrix selected by the selecting means; enhancement range determining means for determining the range of edge enhancement of the target pixel by comparing the calculation result of the calculating means to a specific threshold value; and edge enhancing means for executing an edge enhancement process on data of object pixels within the enhancement range determined by the enhancement range determining means.

The present invention is a medium readable by a computer storing computer-executable programs comprising the steps of determining the presence/absence of an edge at each pixel of input image data; selecting a weighting

3

by reference to the following detailed description taken in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

5   FIG. 1 shows the overall construction of an image processing apparatus;

FIG. 2 is a block diagram of the image processing apparatus;

FIG. 3 is a flow chart of edge enhancement;

10   FIG. 4 shows the coordinates within a block of 3×3 pixels;

FIGS. 5A through 5D show the edge detection matrices;

FIG. 6 shows one example of an enhanced pixel;

15   FIG. 7 shows the target pixel and the edge position;

FIG. 8 shows the target pixel and the edge position;

FIG. 9 shows the target pixel and the edge

20   position;

FIG. 10 shows the target pixel and the edge position;

FIG. 11 shows the coordinates within a block of 5×5 pixels;

matrix corresponding to the position of the edge for each target pixel determined to have an edge; calculating data of the target pixel and pixels surrounding the target pixel using selected weighting matrix; comparing the

5   calculation result to a specific threshold value; determining the range of edge enhancement for the target pixel based on the comparison result; and executing an edge enhancement process for the object pixels within the determined enhancement range.

10   It is desirable that the enhancement range determining means increases the weighting of components corresponding to the interior side of the edge in the weighting matrix.

It is further desirable that the enhancement

15   range determining means selects a weighting matrix based on the presence/absence of an edge in four directions surrounding the target pixel.

It is further desirable that the edge enhancing means executes processing based on the hue and chroma of

20   the pixels surrounding the object pixel.

It is even further desirable that the edge enhancing means executes processing based on the distance of the object pixel to the target pixel.

The invention itself, together with further

25   objects and attendant advantages, will be best understood

4

FIGS. 12A through 12D show examples of
weighting matrices; and

FIG. 13 shows an edge enhancement matrix.

In the following description, like parts are
designated by like reference numbers throughout the
several drawings.

DETAILED DESCRIPTRION OF THE PREFERRED EMBODIMENTS

The embodiments of the present invention are
described hereinafter with reference to the accompanying
drawings.

The image processing apparatus of the present
embodiment of the invention has a controller 1 at it's
center for controlling the overall image processing
apparatus provided with a CPU. In FIG. 1, the arrows
represent the flow of data. A display 2 displays images
or text and the like, and displays various types of
screens for operation. A keyboard 3 and mouse 4 are used
for various input and specified operations. A floppy
disk 5 and hard drive 6 are data storage media for
storing and saving image data, and the image processing
apparatus is provided with a floppy disk drive and a hard
disk drive for accessing the floppy disk 5 and the hard
disk 6. A printer 7 prints the image data and the like
on paper. A scanner 8 reads image data from a document.

A CD-ROM 9 is a storage medium for storing large amounts
of various types of image data, and the image processing
apparatus is provided with a CD-ROM drive to access the
CD-ROM 9. A speaker 10 for audio output and a microphone
11 for audio input are connected. An image processing
program described later is read from an external storage
medium such as the CD-ROM.

FIG. 2 is a block diagram centered on a
controller 1. The controller 1 has a CPU 201 at it
center, and connected to this CPU 201 via a data bus 220
are a ROM 203 for storing various processing programs and
the like, RAM 204 for storing programs and various data,
display control circuit 205 for displaying image and text
and the like on the display 2, keyboard control circuit
206 for controlling and transferring input from the
keyboard, mouse control circuit 207 for controlling and
transferring input from the mouse, floppy disk drive
control circuit 208 for controlling the floppy disk drive,
hard disk control circuit 209 for controlling the hard
disk, printer control circuit 210 for controlling output
to the printer 7, scanner control circuit 211 for
controlling the scanner 8, CD-ROM drive control circuit
212 for controlling the CD-ROM drive, speaker control
circuit 213 for controlling the speaker 10, and a
microphone control circuit 214 for controlling the

microphone 11. Furthermore, a clock circuit 202 supplies
various types of clock signals necessary for the
operation of the image processing apparatus. An
expansion slot 215 is connected so as to allow connection

5   of various types of expansion ports via the data bus.

The controller 1 performs various types of
image processing on a digital image. The digital image
edge enhancement process is described below. FIG. 3
shows the flow of the edge enhancement process performed

10   by the controller 1.

First, image data in the RGB color system are
converted to image data in the HSL color system (step
S10). Then, steps S11-S18 are steps of the edge
enhancement process performed on the L component of the

15   image data in the HSL color system of a specific target
pixel, and these steps are repeated until the edge
enhancement process has been performed on all pixels.

In step S11, a filtering process is executed to
detect the edge. Specifically, a 3×3 pixel block

20   comprising a target pixel and the surrounding pixels is
extracted, and the block is filtered. The coordinates
within this block are defined as shown in FIG. 4. The
pixel at coordinates (2,2) is the target pixel. The edge
detecting matrices w1 used in this filtering is shown in

25   FIGS. 5A through 5D. For example, FIG. 5A is a filter

for detecting an edge present above the target pixel, and

the edge is detected by comparing the value of θ1a

determined by equation (1) below to a specific threshold

value.

$$\theta 1a = \left| \sum_{i=1, j=1}^{i=2, j=3} X_{ij} w l_{ij} \right| \tag{1}$$

Where Xij represents the value of L at

coordinates (i,j), and wlij represents line i column j

component of the edge detecting matrix wl.

Similarly, FIG. 5B is an edge detecting matrix

for detecting an edge present below a target pixel, and

the edge is detected by comparing the value of θ1b

determined by equation (2) below to a specific threshold

value.

$$\theta 1b = \left| \sum_{i=2, j=1}^{i=3, j=3} X_{ij} w l_{ij} \right| \tag{2}$$

Similarly, FIG. 5C is an edge detecting matrix

for detecting an edge present to the left of a target

pixel, and the edge is detected by comparing the value of

θ1c determined by equation (3) below to a specific

threshold value.

$$\theta 1c = \left| \sum_{i=1, j=1}^{i=3, j=2} X_{ij} w l_{ij} \right| \tag{3}$$

Similarly, FIG. 5D is an edge detecting matrix

for detecting an edge present to the right of a target

9

pixel, and the edge is detected by comparing the value of

$\theta 1d$ determined by equation (4) below to a specific

threshold value.

$$\theta 1d = \left| \sum_{i=1, j=2}^{i=3, j=3} X_{ij} w l_{ij} \right| \qquad (4)$$

5   In the present embodiment, the edge between

pixels is determined as described above. In this way

edges are naturally enhanced without enhancing only lines

by increasing the difference between both pixels

circumscribing the edge during enhancement. Furthermore,

10   edges present around a target pixel can be limited to

four types by determining the edge between pixels, and

subsequent selection of weighting matrix is simply

accomplished.

          When an edge is detected at a target pixel

15   (step S12: YES), the weighting matrix w2 is selected to

determine the enhancement radius R (step S13). Then, a

block of 5×5 pixels comprising the target pixel and 24

surrounding pixels is extracted, the selected weighting

matrix w2 is used for filtering this block, and the

20   enhancement radius R is determined (step S14). The

coordinates within this block are defined as shown in FIG.

11. FIGS. 12A through 12D show examples of the weighting

matrices w2. FIG. 12A shows a weighting matrix w2 when

an edge is detected at the left side of the target pixel

(FIG. 7), FIG. 12B shows a weighting matrix w2 when edges are detected below and on the left side of the target pixel (FIG. 8), FIG. 12C shows a weighting matrix w2 when edges are detected below, on the left side and on the

5   right side of the target pixel (FIG. 9), and FIG. 12D shows a weighting matrix w2 when an edge is detected on the left and right sides of the target pixel (FIG. 10). In all weighting matrices w2, pixels from a11 to a55 are not 0.

10   The edge enhancement radius R is a parameter representing the range for enhancing the edge, and is used to determine to which pixel to perform enhancement at the peripheral pixels considered as the edge. For example, the enhancement radius is 1 (pixel) in the

15   example of FIG. 6, and the target pixel and surrounding pixels (shaded area) represent the enhanced pixels obtained by edge enhancement.

             Specifically, the enhancement radius R is automatically calculated in accordance with equation (5)

20   below from the image data and weighting matrix w2 using the radius calculation function F(x).

             $R=F(\Sigma x_{ij}w2_{ij})$ (5)

             Where x_{ij} represents the value of L at coordinates (i,j), and $w2_{ij}$ represents the line i column j

25   component of the weighting matrix w2.

The radius calculation function F(x) is a function such as shown in the examples below.

F(x)=1 when b1≤x<b2

F(x)=2 when b2≤x<b3

Where b1 and b2 are constants.

The edge enhancement range (enhancement radius) should be determined from the slope (gradation) of the luminance of the edge periphery and edge line type (thickness). The edge enhancement radius is closely related to the edge width. When the edge enhancement radius is small, the edge width is thin, and when the edge enhancement radius is large, the edge width is thick. The edge thickness must be adjusted depending on the object. The weighting in the weighting matrix w2 is at the opposite side (edge inner side) of the edge position relative to the target pixel. Since the edge enhancement radius is determined using the weighting matrix w2, the determined edge enhancement radius is related to the edge width if an edge is in the periphery of the target pixel. When the object is a building, there is a slope point (edge) of acute change in luminance near the object edge, and when the object is a human image, and particularly the photograph of a face, the change in luminance is smooth near the edge. These characteristics are reflected in the edge enhancement radius.

Then, pixels within the enhancement radius R, i.e., the object pixels for edge enhancement processing, are subjected to the enhancement process using the enhancement parameters. Moreover, characteristics of the object can be reflected since the enhancement parameters are determined from the color information and chroma information near the edge. First, the enhancement parameter is calculated for the value $L(i,j)$ of the image data of one object pixel (step S15), and the enhancement process is executed (step S16). This enhancement process is repeated until processing is completed for all object pixels within the enhancement radius R (step S17: YES).

A first enhancement coefficient P1 and a second enhancement coefficient P2 are included in the enhancement parameters, and are calculated from the color information and the enhancement radius as described below.

The first enhancement coefficient P1 is determined from the color information and chroma of the surroundings, i.e., from image data of the target pixel and the eight surrounding pixels. As shown in Table 1, four types of color (neutral color, flesh color, warm color, other) are discriminated to determine the first enhancement coefficient P1.

Table 1

Color	P1	Reason

13

Neutral color	0.6	Enhance text edge
Flesh color	0.7	Produce skin texture
Warm color	0.7	Soft tones are unnatural with hard edges
Other	1.0	

The second enhancement coefficient P2 is determined by the distance from the center pixel of the enhancement. As shown in Table 2, the second enhancement coefficient P2 is calculated for distances 0, 1, 2 (pixels).

Table 2

Distance	P2
0	1.0
1	0.8
2	0.6

The corrected image data L'(i,j) are calculated by equation (6) below using the uncorrected image data L(i,j), the two enhancement coefficients P1 and P2, and the edge enhancement matrix w3 shown in FIG. 13.

$$L'(i,j)=L(i,j)+W*P1*P2 \qquad (6)$$

$$W=\Sigma L(i,j)*w3ij \qquad (7)$$

Where w3ij represents the line i column j component of the edge enhancement matrix w3.

Although the present invention has been fully described by way of examples with reference to the accompanying drawings, it is to be noted that various changes and modification will be apparent to those skilled in the art. Therefore, unless otherwise such changes and modifications depart from the scope of the present invention, they should be construed as being included therein.